

MODIS
Terra Normalized water-leaving radiance
Data Quality Summary

Last updated: August 6, 2002

Investigation: MODIS

Data Product: Normalized water-leaving radiance (MOD18)

Data Set: Terra

Data Set Version: Collection 4 version 4.2 reprocessed
Dates: launch through March 2002

Status: Validated

Nature of the product

The water-leaving radiance (L_w) is the radiance exiting the sea surface, i.e., solar irradiance backscattered into the atmosphere from beneath the sea surface. The *Normalized* water-leaving radiance (nL_w) is L_w normalized in a manner that removes most of the effects of variations of the solar zenith angle (Gordon and Clark, 1981). This radiance carries information regarding the concentration of marine biota, etc. MODIS provides the top-of-atmosphere radiance data (L_t) that allows estimation of (nL_w) in seven spectral bands (Bands 8 – 14) centered at wavelengths 412, 443, 490, 531, 551, 667, and 678 nm. For typical marine atmospheres and oligotrophic waters (the brightest in the blue), nL_w composes approximately 10% of L_t in the first three bands (412-490 nm), 4% of L_t in the green bands (531 and 551), and ~ 0.4% of L_t in the two red bands. The rest of the radiance is backscattered from the atmosphere and the sea surface. The water-leaving radiance is extracted from L_t through a process referred to as atmospheric correction. Clearly, atmospheric correction is particularly challenging in the green and red portions of the spectrum. In addition, the MODIS calibration requirements are very exacting, e.g., a 1% error in calibration in the blue, green and red spectral regions is equivalent to an approximately 10%, 25%, and 250% in nL_w error, respectively.

The procedure for atmospheric correction is detailed in the (MOD18) ATBD available at http://modis.gsfc.nasa.gov/data/atbd/atbd_mod17.pdf. It uses the fact that nL_w is negligible in the near infrared (NIR) bands at 749 and 869 nm (Bands 15 and 16). Thus these bands are used to estimate the atmospheric contribution. In collection 4 V4.2 improvements were made to the NIR atmospheric correction to allow some water leaving radiance to be present at 749 and 869 nm (Siegel *et al.*, 2000).

Data Accuracies

The MODIS atmospheric correction algorithm is virtually identical to that used in SeaWiFS processing. Actually the SeaWiFS and MODIS algorithms are the result of a research effort focussed on development of algorithms for MODIS, e.g., see Gordon and Wang (1994) and Gordon (1997). The validation of the SeaWiFS nL_w product is discussed in detail in Hooker and McClain (2000). An updated description of the validation results based on the third reprocessing of the SeaWiFS data set is available at (http://seawifs.gsfc.nasa.gov/SEAWIFS/TECH_REPORTS/PLVol10.tex_typeset.pdf). This report indicates that for the bands at 443 – 555 nm the ratio between of nL_w derived from SeaWiFS to that measured in situ (SeaWiFS:In situ) varied from 0.95 to 1.10 with a standard deviation of ~ 0.25 . At 412 nm the ratio was 0.85. The comparisons generally cluster around the 1:1 line; however, at 412 nm at lower values of nL_w the SeaWiFS values tend to be lower than the in situ values. These lower values are partially due to stray light effects in the *in situ* data at the MOBY (Clark *et al.*, 1997) calibration site, and are believed to have been reduced in the forth SeaWiFS reprocessing. It is important to note that, except in turbid waters, the error in atmospheric correction is independent of the water properties, so as nL_w decreases the *relative* error in nL_w increases.

At the present time (July 2002) detailed nL_w validation data are available only for the MOBY calibration site, so detailed comparisons can only be made for that location. Comparison at the MOBY buoy site show excellent agreement, with RMS values on the order of twice the RMS in the *in situ* measurements (Table 1).

Table 1 MOBY-MODIS nL_w RMS

Band	% RMS
412 nm	10.5
443 nm	7.5
488 nm	4.5
531 nm	6.7
551 nm	7.3

In conjunction with Ewa Kwiatkowska of the SeaWiFS/SIMBIOS project, a time series of 18 days of V4.2 MODIS 4.63 km binned products were compared to same day retrieval SeaWiFS products binned to the same 4.63 km spatial resolution as MODIS, Figure 1 (only 412 and 443nm shown). The SeaWiFS data was from reprocessing 4 calibrated against stray-light corrected *in situ* data. The MODIS/SeaWiFS matchups include only collocated bins that had been assigned the highest quality for both sensors. For the linear fits shown, the bisector of the MODIS vs. SeaWiFS and SeaWiFS vs. MODIS was determined and the distance perpendicular to this line was used in calculating the weights. Thus, there is no true independent variable and the presence of errors in both sensors is assumed. The nL_w comparisons show good agreement, generally <3% difference.

These comparisons place the normalized water-leaving radiances for the spectral range 412-551 nm in the validated (Stage 1) status. Validated (Stage 1) means that comparisons with surface data at a limited number of locations (MOBY) and with other (validated) space-borne sensors (SeaWiFS) have been carried out successfully, leading to an estimate of the uncertainty in the validated quantity. (For a complete description of the validation stages see <http://modis-ocean.gsfc.nasa.gov/datamaturity.html>.) The normalized water-leaving radiances at 667 and 678 nm (the fluorescence bands) cannot be validated through comparison with surface measurements, as the latter are imprecise at this time due to the small magnitude of the radiances. These bands can only be validated indirectly, i.e., in the sense that they produce fluorescence line heights (MOD20) in agreement with oceanic observations. Validated fluorescence line heights essentially mean that the radiance difference between the 667 and 678 nm bands is within expectation; however, the absolute radiances may still contain unquantifiable uncertainty.

Note that in Figure 1 there is a change in the relationship after 2002 day 69 (March 2002). This is after a period when MODIS shut down temporarily and resulted in a calibration change when the sensor was reactivated. New Level-1B v 4 calibration tables will be implemented in the near future and data collected after March 2002 will need to be reprocessed. Thus the validated status is only applicable for Collection 4 v4.2 for the period October 2000- March 2002.

Cautions When Using Data

Retrieved top of the atmosphere L_t 's have an apparent stability floor of 0.1-0.3%. This translated to nL_w uncertainty as a 2-3% RMS for the blue bands and 20-30% for the red band and applies at both detector to detector and mirror side errors. These uncertainties redistribute with time such that different detectors within a scan, cross scan behavior, and mirror side balance will shift in time. At this moment, these instabilities have no obvious correlation to any known factors. An example of this type of instability can be seen in the mirror-side waterfall plots over the MOBY validation site in Figure 2.

While these instabilities are observed in high resolution 1km level-2 granules and result in occasional striping, artifacts due to these instabilities are much reduced or absent in the lower resolution global products. Visual examination of the lower resolution global images indicates that principally in March and surrounding months in the Northern Hemisphere there is a tendency for the East side of the Western passes to be higher in radiance than the Western side of the adjoining Eastern pass. This discontinuity is reversed in the Southern Hemisphere. This transition dislocation precedes the equinox and is most pronounced in the spring equinox, and is not apparent in either the winter or summer.

Users should be aware that calibration of oceans bands and validation is tightly coupled to the underlying Level 1B instrument calibration tables. Validated status has been

declared only for reprocessed oceans V4.2 products created using Level 1B v3 input radiances covering the period from launch through March 2002 only. Products produced after April 2002 remain provisional until new calibrations have been developed for use with Level 1B v4 and in situ match up analysis can be extended.

Expected Revisions

The revisions in the processing code will mainly reflect improvements in the on-orbit characterization of MODIS. In particular, as more validation data become available, they will provide better understanding of the MODIS response-versus-scan-angle effects, detector-to-detector sensitivity variation, and the MODIS polarization-sensitivity correction. As this understanding leads to improvement of the processing, this document will be updated to reflect the expected data accuracies.

Quality Assurances

There are four levels of quality for the nL_w 's. These are based on the values of certain flags related to atmospheric correction (<http://modis-ocean.gsfc.nasa.gov/qa/>). There are two kinds of flags – Common flags and Product Specific flags. Most of the Product flags are for diagnostic purposes, others reflect some failure of the processing.

In the common flag, bits are set as follows:

- Bit 1 – Pixel not processed
- Bit 2 – Atmospheric correction failed
- Bit 3 – Satellite zenith angle > 55 Deg.
- Bit 4 – Solar zenith angle > 70 Deg.
- Bit 5 – Shallow water
- Bit 6 – Sun glint (predicted reflectance > threshold) or cloud
- Bit 7 – Invalid or missing ancillary data
- Bit 8 – Land

In the product specific flag that includes nL_w , flag bits are set as follows:

- Bit 1 – Contribution from molecular scattering could not be computed.
- Bit 2 – $nL_w(551)$ too low (< Threshold)
- Bit 3 – Bright water – Coccolithophores detected (Brown and Yoder [1994] test)
- Bit 4 – (Not related to nL_w)
- Bit 5 – Aerosol contribution too large (AOD at 865 nm > Threshold)
- Bit 6 – (Not related to nL_w)
- Bit 7 – (Not related to nL_w)
- Bit 8 – Absorbing aerosol (not implemented)
- Bit 9 – Cloud (Albedo > Threshold)
- Bit 10 – One or more bands missing.

Bit 11 – Any $nL_w < 0$. (Bands 8-14)
 Bit 12 – Any invalid L_t value (e.g., saturated)
 Bit 13 – Not used
 Bit 14 – Aerosol correction failed.
 Bit 15 – $\epsilon(749,869)$ out of range.
 Bit 16 – Aerosol contribution $(L_t - L_r) < 0$ in Bands 15 and 16

The quality levels range from 0—3 according to the setting of various flags above. Quality Level 0 indicates no known problems, Quality Level 3 indicates that the data are unusable. The Quality Levels are related to the Common and Product flags as follows:

Quality Level 0: No Common or Product flag bits set.
 Quality Level 1: Common flag bit 3 (Satellite Zenith Angle > 45 Deg.) set
 Quality Level 2: Common flag bit 6 (Sun Glint above threshold or cloud) set.
 Quality Level 3: Common flag bit 2 (Failed Atmospheric Correction) or bit 8 (Land) set, or Product flag bits 10, 11, 12 (Impossible nL_w) set.

References

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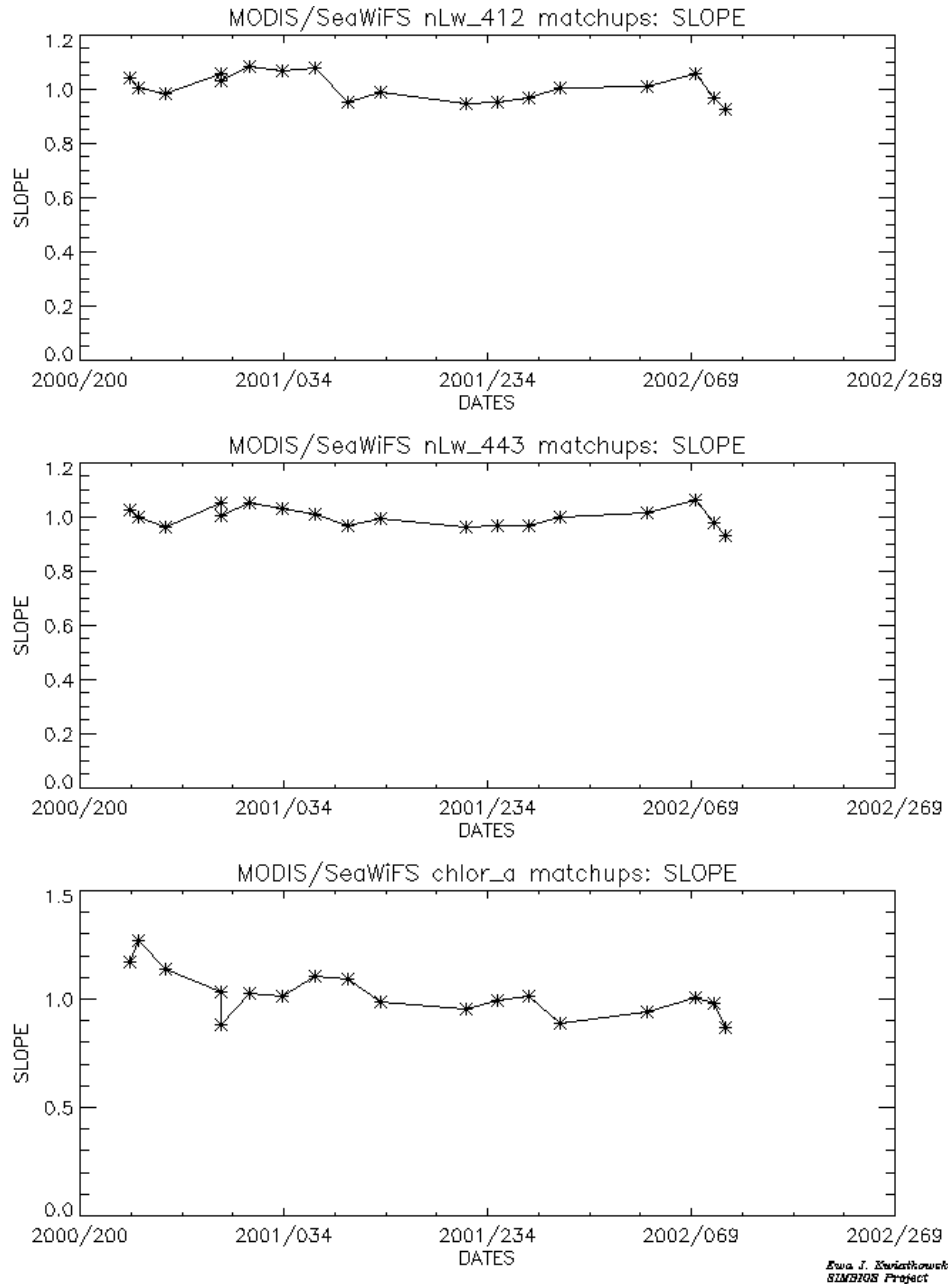


Figure 1. Time series of slope MODIS/SeaWiFS global 36km comparisons for nL_w at 412 and 443 nm and for Chlorophyll a .

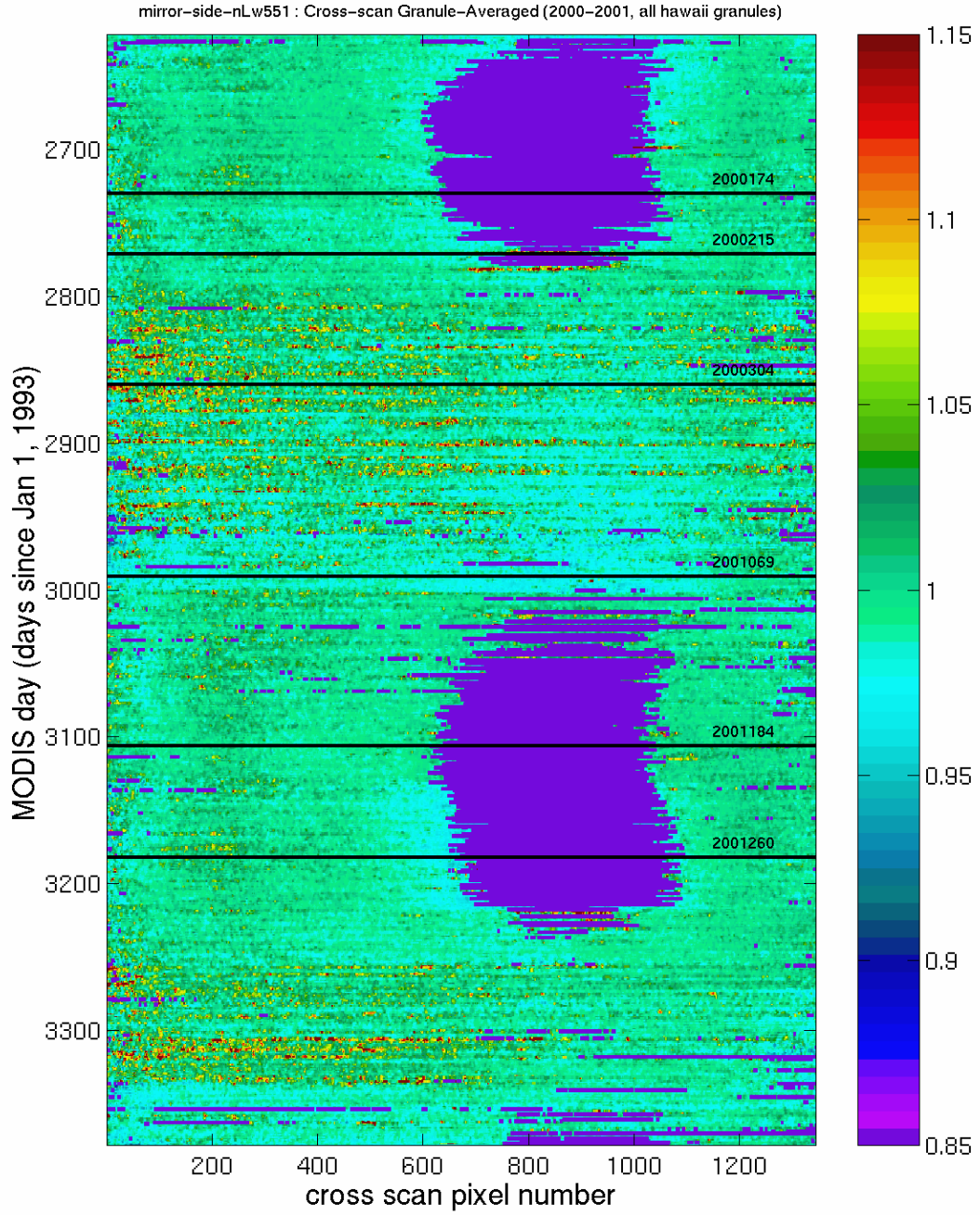


Figure 2: Mirror side Waterfall plots for the nL_w at 551 nm time series. The cross-scan (abscissa) behavior of the mirror side difference (colors) in mission time (ordinate). Each time record is a complete granule average. Changes in mirror-side/cross-scan behavior apparent within each calibration epoch is to noise at the 0.1-0.3% level in L_t .